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AN ANALYSIS OF MULTIPLE USE BUILDINGS

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ABSTRACT

Multiple use buildings include such functions as apartments, offices, parking, condominiums, and shops. The multi-use concept is growing in popularity among developers and builders. Reasons for this growth are because multiple use buildings can help rejuvenate urban areas, conserve energy, prevent crime, eliminate city canyons, and reduce overcrowding on sidewalks.

The structures that go with multi-use buildings, called megastructures, utilize many new design and construction ideas. These buildings also incorporate innovative architectural and elevator characteristics.

Results of studies on multi-use buildings indicate a high user satisfaction. People enjoy the opportunity to live, shop, or even work in the same building. However, more research needs to be done on the psychological aspects of living and working in the same building.

1. INTRODUCTION

The purpose of this thesis is to give an overview of multi-use buildings. Some papers and articles discuss specific aspects of multi-use buildings; however, no paper to date collectively discusses the numerous components of the multiple use building concept.

An examination of the concept of a single building containing multiple functions will be presented in section two. The history and subsequent growth of multiple use buildings will then be reviewed. This will be followed by sections on their economic and structural practicality; the structural characteristics of multi-use buildings, including engineering and architectural systems; the psychological and social implications; and case studies of three noted multiple use buildings.

This research is needed to update information relating to multi-use buildings themselves and their interaction with society today. This report is to supplement the Tall Building Monograph, a five volume study which incorporates many details for the planning and design of tall buildings (Council on Tall Buildings, 1978-1981).

2. THE CONCEPT OF A MULTI-USE BUILDING

Traditionally, tall buildings were designed to serve only one purpose, for instance just office space or apartments. Current design trends, however, are combining various uses into one structure. An example of this is a building housing office space as well as apartments and entertainment facilities. Numerous combinations of accommodations are referred to as multi-use buildings. Prominent examples of successful multi-use buildings include the John Hancock Center in Chicago (Fig. 1), the Citicorp Center in New York (Fig. 2), Water Tower Place in Chicago (Fig. 3), the Omni in Atlanta, and Fox Plaza in San Francisco.

To thoroughly investigate the concept of multiple use one must incorporate other variables besides the combined uses. The environmental and societal needs of the public must be considered as well. Le Corbusier, a noted French architect, saw this problem for both buildings and entire cities as far back as 1933. He states in his book, "The Radiant City":

> "We must concern ourselves with man! Which means, to design and lay out the sites, to construct the vessels that will be capable of containing useful activities."

Ada Louise Huxtable, architecture critic for the "New York Times", elaborates on this point some forty years later. She states (1972):

> "What counts overwhelmingly today are the multiple ways any building serves a complex and sophisticated set of environmental needs. What is it part of? How does it work? How does it satisfy the needs of men and society as well as the needs of the client? How does it fit into the larger organism, the community? What does it add to, or subtract from, the quality of life?"

A multi-use building is a single building with multiple uses. An example of this is Water Tower Place in Chicago. Its twelve story base incorporates shops and offices while a hotel and condominiums are located in a 64-story tower rising from the base. Other buildings of this type are Hartford Square North in Hartford and the Olympic Tower in New York. A tabulation of all multi-use buildings is shown in Table 1 for the United States and Table 2 internationally.

A group of connecting buildings with various uses is not a multi-use building. Terms for these structures are urban activity centers or multi-building developments. The Rennaisance Center in Detroit illustrates this type. The tall center building is a hotel while the four surrounding tall buildings contain offices. These buildings are connected at the base but each building remains a separate entity. Other grouped buildings include the Galleria Complex in Houston and the Peachtree Center in Atlanta.

One structural characteristic all multiple use buildings have is the megastructure. As Beedle describes it (1977):

> "The structures to go with multiple or mixed use, called "megastructures", will provide new creative challenges to the structural engineer. Such structures frequently will be unique in form. Some will be sucessful, some not; the methodology is still developing. They will contain provision for nearly every function that a building can provide, and all under one roof: housing, office, hotel, shops, restaurants, supermarket, industry, health care, education, recreation, and entertainment. One can imagine the design complexity -- and the options."

All megastructures are one building, yet that building can be one large tower in itself or a tall central high-rise structure emerging amid low-rise segments.

Multi-use is not to be confused with the term "mixed construction." Mixed construction refers to the use of two or more different construction materials in the structural system of the building.

3. HISTORY AND GROWTH OF MULTI-USE BUILDINGS

Historic European towns used multi-use buildings with stores on the first floor and apartments above. Many general stores which existed in the early years of the United States followed this same principle. In small towns today, buildings in the main business area utilize their lower floors as shops and stores while the second and third stories are apartments or office space. So the general concept is not new.

What about the development of multiple usage in tall buildings? Tall buildings have been designed and constructed for nearly one hundred years. These buildings became increasingly popular only after Elisha Otis perfected the elevator with an automatic brake as a means of safe vertical transportation. The idea of incorporating multiple uses into a tall building had its origin dating to the late 1800's. One of the first notable proposals was by Theodore Starrett in 1906 (Goldberger, 1981). He suggested a 100-story building which had industry at the base, business above, residences in the next section, and a hotel. Each section was separated by shops and theaters. An amusement park, a roof garden, and a swimming pool were included in the top section of the building. This proposal was not realized, but the concept of multi-use gained in popularity (Goldberger, 1981).

Other multi-use buildings, possibly less spectacular than Starrett's 100-story tower, but still attractively designed, were actually constructed in this time period. The Auditorium Building in Chicago was one of these. It was designed by Adler and Sullivan and built in the late 1800's. A hotel, office tower, and facilities for the performing arts were contained in the building (Goldberger, 1981). Another of these buildings was the Hudson Terminal Building in New York, built in 1908. Promotional literature on the building stated:

> "The massive arcades constitute a veritable city, with their varied shops, stores, counters, and sales places, vending most everything desired from fruits, food, and candy, to wearing apparel, hardware, and household items."

A number of multi-use buildings were completed in the 1920's and 1930's, but the majority of tall buildings were constructed for a single function. The Terminal Tower in Cleveland is one significant multi-use building which emerged in this era. This 700-ft., 52-story complex contained offices, a hotel, a railroad station, a rapid transit station, a department store, restaurants, and banks. This was one of the first skyscrapers in which the design incorporated the social needs of the urban community. As Goldberger states (1981): "So Terminal Tower controlled its city's skyline, yet it wove itself into the fabric of the city at the same time." The multi-use aspect was a key factor in this integration. Other major multi-use buildings constructed at this time were the Carew Tower in Cincinnati and the Pittsfield Building in Chicago.

The decade of the forties was very slow for tall building construction due to World War II. In the Council's High Rise Building Data Base (Council on Tall Buildings, 1980), only 16 out of the 2756 buildings which have known completion dates were built in that decade. This interrupted the further evolution of multi-use buildings.

A few new multi-use buildings were produced in the fifties, but the major surge toward the multi-use concept came in the decade of the sixties. Figures 4 and 5 show this escalating growth of multi-use buildings in the United States and internationally. The Marina Towers in Chicago were one set of multi-use buildings constructed at this time. The towers are shown in Fig. 6. Through the 1970's the number of multi-use buildings increased. Unique structural systems and innovative ideas such as double deck elevators and sky lobbies came forth. At this time more professions were consulted in the design of many tall buildings. Instead of just the architect and structural engineer, these projects included input from urban planners, landscape architects, and social scientists (Beedle, 1977a).

Today, multiple use buildings are being built on a much larger scale. Professional engineering magazines frequently mention new multi-use buildings being planned or under construction. A growing number of clients are choosing the multiple use alternative to accommodate their needs (Khan and El Nimeiri, 1982).

According to the table of tall buildings in Volume SC of the Monograph, the total number of tall multi-use buildings in the United States is 69. This amounts to 6.0 per cent of all tall buildings. Internationally (excluding the U.S.), 152 of 1655 tall buildings (9.2 per cent) include multiple uses. A breakdown of the number of buildings according to use is shown in Tables 3 and 4. During the course of research, twelve other multiple use buildings were identified in the United States. All 81 multi-use buildings known to date in the United States are listed in Table 1.

Multi-use buildings will probably continue to be a most significant trend in future tall building construction.

A few approaches have been proposed for extraordinary multiple use structures. One is that of Paulo Soleri, a noted architect and self proclaimed "arcologist". He has proposed a massive multiple use structure for the Arizona desert (Soleri, 1971). This structure would be a city in itself and would house approximately two million people. The final plans call for a mile high tower surrounded by smaller buildings, all being connected by a large base (Soleri, 1971). Figure 7 shows the concept. A pilot city for 5000 people is now under construction in the desert by Soleri and other laborers who reside at the site while working. These same people intend to live in the city when completed (60 Minutes, 1981). Other visions of Soleri call for the same type of mile high system to be a floating city in the ocean. This would have the living area above water, commercial space below, and industrial areas toward the bottom (Spectrum, 1976).

A community living concept is the second unique idea. Two Illinois Institute of Technology professors, Pao-Chi Chang and Alfred Swenson, performed a study of ultra-high rise community living (Chang and Swenson, 1974). The main feature of the study was to include large, open, landscaped areas or "sky gardens" in the structure to improve the quality of living for the inhabitants. Ten floors of apartments would share the large open area intended to form a neighborhood focal point. The 150 - 200 story building incorporates offices, shops, a hotel, apartments, and various entertainment facilities. The land around the building is also very important to the project. It would be developed with recreation areas so residents could enjoy outdoor activities. Results of this in depth study concluded this building type to be very economical and feasible.

Possibly the most feasible of these extraordinary multi-use buildings is proposed for downtown Chicago. It is a 2300-foot megastructure incorporating offices, condominiums, shops, and a hotel. Millenson (1981) states that the major problem with this building would be financing the 1.25 billion dollar structure. A comparison between the heights of this building and the John Hancock Center, which is the tallest multi-use building to date, is shown in Fig. 8.

4. WHY MULTI-USE BUILDINGS ARE PRACTICAL

One major reason for constructing multi-use buildings is to return people to the downtown area; however, many other problems can be alleviated by their use. It has been suggested that land consumption, energy waste, and crime can be reduced by constructing multi-use buildings.

4.1 DOWNTOWN REJUVINATION

Government officials of many major municipalities were concerned by a tremendous loss of interest in the downtown area (Ross, 1981). Chicago was one such municipality. Developers decided to erect a set of buildings downtown which would include a variety of services and be an attractive alternative to suburbanites. The Marina Towers, which included shops, offices, and apartments, resulted. As mentioned previously, these buildings were constructed at the beginning of the recent trend toward multiple use structures.

Chicago's Marina Towers and other recently constructed multi-use buildings have been successful in their effort to attract people to the downtown area by creating attractive living spaces. However, many people are still moving away from large cities to urban fringe areas. This is especially true in developed countries (Council on Tall Buildings, 1981). As these areas grow, they destroy valuable farmland at an alarming rate. In New York alone, approximately 81,000 acres per year of available farmland is being taken away by new suburbs. For the total United States, an area the size of Connecticut is lost each year (Cornucopia Project, 1981).

4.2 ENERGY SAVINGS

The movement of people to the suburbs creates another problem, a sizeable expense of energy. A car is used almost every time a suburban resident travels. Due to subdivision locations being a long distance from the city, more driving is required to reach various destinations. This can quickly add up to hundreds of miles driven per week and many gallons of fuel used. Multiply this by the number of drivers in the suburbs and the quantities become considerable. If a fraction of these people chose the multi-use alternative, they could live, work, shop, and find entertainment within the building resulting in notable energy savings. It even could become unnecessary to purchase a car.

Another type of energy savings would be realized due to the twenty-four-hour use of the multi-use building. Office buildings are used approximately ten to twelve hours a day, and yet they are heated or cooled to some degree all day and night. Because people utilize multiple use buildings at all hours, the power supplied in the usual off hours is not wasted.

4.3 CRIME PREVENTION

Making use of a building twenty-four hours a day also helps deter crime. People will be entering and leaving at all hours, inhibiting potential crimes due to the increased possibility of being seen or interrupted (Council on Tall Buildings, 1981).

4.4 VERTICAL CANYON EFFECT

Another problem of downtown areas which multiple use buildings can help to alleviate are "city canyons." In the early twentieth century, these canyons were formed by constructing block after block of bulky, stone or concrete tall buildings. The sun could only reach the street for a few hours at midday and fresh air was rarely felt at street level. Hence, "city canyons" (or vertical canyons) were formed in these central business districts (Khan, 1972).

Some multi-use buildings are being designed which can have the effect of alleviating the vertical canyon problem. An example of this is Water Tower Place. The building has a tall, slender tower rising from a large base. The uses of the tower dictated its shape. Since the tower does not cover the entire area of the site, sunlight can reach street level throughout a greater part of the day. Another example is People's Park in Singapore.

4.5 OVERCROWDING

Plazas are important in reducing the overcrowding of city sidewalks. In usual businesses, many workers end their day at five o'clock. This creates a chaotic rush toward the exits at this time, and a congested situation on normal sized sidewalks. Plazas tend to thin the crowds by providing more space to walk.

The buildings themselves can aid in reducing overcrowding at peak rush hours. If the offices dismiss at five o'clock, the workers have several options. Those who live there would take the elevator to their apartments, some workers might stay in the building to go shopping or to a movie, and some will leave. This could cut down on the large number of people exiting the building at one time. Each service housed by this complex has a different peak hour. This, too, controls the fluctuation of pedestrian flow throughout the day.

Another way multi-use buildings reduce the crowding issue is to have different entrances and elevators for each function of the building. Water Tower Place is a good example of this. Its basic floor plan is shown in Fig. 9. The main entrance and elevators for the hotel and condominiums are in one corner, the main entrances for shopping are in another area, and the entrance and elevators for the offices are in yet a third area. Interconnecting malls and atriums allow free passage between functions but any crowding is certainly reduced (ENR, 1975).

5. DESIGN CHARACTERISTICS OF MULTIPLE USE BUILDINGS

Of the many systems involved in the tall building, three that are of primary importance are architectural, structural, and vertical transportation. Novel building features have been introduced in multi-use buildings. Unique structural systems have been developed, new architectural concepts have been created, and updated elevator systems have been utilized. It is of interest to see how these are affected by the multi-use concept.

5.1 STRUCTURAL SYSTEMS

Four basic structural material possibilities are available (Falconer, 1981). These are: steel, concrete, mixed construction, and masonry. Each of these groups have certain design systems which are economical for various heights. An introduction to each material type is presented here to familiarize the reader and to show major structural systems used in multi-use building construction.

The seven main steel structural systems are shown in Fig. 10. These systems are plotted against feasible design heights (Khan, 1974a). The main advantages of steel are that a fast erection time is realized and large open spaces can be incorporated. Presently, multi-use buildings use structural systems up to the 100-story truss-tube. The John Hancock Center is such a system. No multi-use buildings to date utilizing the bundled tube system are known to the author.

Figure 11 shows six major concrete structural systems for office buildings (Khan, 1974a). Many of these systems can also be used for multi-use structures. The primary advantages of concrete are inherent stiffness, shallow floor depths, and easy maintenance.

Water Tower Place uses a modified tube system, similar to the modular tube office building system shown in Fig. 11.

Two other multi-use buildings with concrete structural systems are presently being constructed in Chicago. One Magnificent Mile incorporates a bundled tube structure (Khan and El Nimeiri, 1982). The PSM International building uses a concrete X-bracing system similar to the steel system used in the Hancock Center (Khan, 1981).

The mixed construction alternative is a relatively new design concept. This system combines the aforementioned advantages of both steel and concrete. Two distinct systems exist which utilize the advantages of each in different ways.

One system has the lower portion of the building constructed with steel and the upper portion with concrete. Offices would locate in the steel section due to the large open spaces resulting from the long spans. A hotel (or apartments) would be appropriate in the concrete section taking advantage of of the shallow floor depths and easy maintenance. A major problem occurs at the concrete-steel interface of the system. Unique challenges exist in designing methods to transfer wind loads from the concrete portion to the steel portion (ENR, 1974). Also, columns will not necessarily line up from section to section, so further problems are created. The Olympic Tower, a multi-use building in New York, uses a concrete-steel structural system. This building deals with the transfer problems by incorporating horizontal trusses in the transition floor to take vertical and lateral loads (ENR, 1974).

To what extent does the multiple function aspect affect the structural system of the building? This issue can be broken down into two parts. One part deals mainly with interior structural characteristics while the other area refers to the general type of structural system as described in the previous paragraphs.

Some interior design components of multi-use buildings are: interior column spacing, spandrel beam shape and size, floor-to-floor height, type of ceiling, transfer levels, and floor plans (Khan and El Nimeiri, 1982). Water Tower Place, shown in Fig. 3, is a good example of how these design factors can be taken into account. The client initially wanted the multi-use concept. The uses of the tower were a prime consideration in the decision to create a concrete structure. Long spans were not needed for the apartments and hotel, and therefore two-way flat slab construction could be used in those portions. The concrete slab undersides could be suitably finished, so drop ceilings were not needed. This eliminated eighty feet of the buildings height. The modified tube system was also chosen because of the uses planned for the tower. In pure tubular design, exterior columns are connected by deep spandrel beams. With residential usage, expansive views are important. Deep spandrels would reduce this view, so a modified system using shallower spandrels and a shear wall was adopted. Steel was abandoned by the designers as a possible base due to problems created by a concrete-steel interface at the twelveth story. It is evident then that the uses of the tower were a major factor in determining the structural system of the building (ENR, 1975).

The John Hancock Center illustrates the effect multi-uses can have on the general structural system. The initial and final design concepts are shown in Figs. 12 and 13. If the first scheme would have been constructed, two sixty to seventy story structures would have been required. Assuming steel as the material, the economical design type for the buildings (from Fig. 10) would have been either the frame-shear truss or the belt truss. Because the designers decided to use one building to accommodate all uses, a much taller building was required. This additional height led to a totally different structural system. Therefore, the structural system for the John Hancock Center was definitely affected by the decision to make it multi-functional (Iyengar, 1973).

One recent example of a multi-use building in which the general structural system was not affected by the various functions is the new sixty story building under construction in Chicago for PSM International. Khan had the idea for a concrete building using the X-bracing principle. PSM International wanted multiple uses and they bought this idea. In this case, the idea for the type of structural system was initiated and then the multiple uses were added (Khan, 1981).

5.2 ARCHITECTURAL CHARACTERISTICS

One architectural system is the actual layout of the various functions in the building. Commercial areas and parking facilities are usually located on the lower floors to attract people from street level. Apartments and hotels are usually located on higher floors to provide more pleasant views. Again, the John Hancock Center is a good example of this. As shown in Fig. 14, the building has parking and commercial areas on the lower floors, offices on the next forty and apartments above that. A restaurant and observatory are located at the top. This was a logical arrangement, putting the offices in the larger lower floors and the apartments above. Since the view and natural lighting are key factors for apartments, they must border the outside walls of the building (Iyengar, 1973). Offices, however, can utilize the entire area from the core to the windows. For this reason, the apartments were located in the smaller upper half of the building and the offices below. Larger apartments are on the lower living floors while the one bedroom apartments are nearer the top of the structure (Iyengar, 1973).

The atrium is another architectural characteristic which facilitates multi-use. An atrium, which could be called an indoor plaza, can be an area for public use. People can meet friends, sit and listen to a band, or eat lunch in these areas. And because atriums are enclosed, there is no need to worry about heat, cold, or inclement weather. In Water Tower Place, twenty-five percent of the area on the commercial floors is taken by atriums (ENR, 1975). The Citicorp Center also includes a large atrium.

An architectural feature that requires special attention in multi-use buildings is the separation of public areas from private areas. In one solution, living areas are grouped on upper floors and public areas are in the lower portion of the building. Separate entrances and dedicated elevators also can help to maintain this privacy.

5.3 ELEVATOR CHARACTERISTICS

The sky lobby concept is one system associated with elevators. Lobbies are situated on different stories in the building to serve a local group of floors. High-speed elevators are used to shuttle people from street level to the sky lobby, and then local elevators convey the people to their specific floor (Council on Tall Buildings, 1980). This is one way to separate people quickly so crowding conditions do not result. Multi-use buildings could employ sky lobbies very effectively. Consider the hypothetical case of a building which has offices on the first thirty stories, a hotel on the next twenty, and apartments on the top thirty. Two sky lobbies could be employed very beneficially here. The hotel could have its own lobby for registration on floor thirty-one. The apartments could have a sky lobby on floor fifty-one for recreation. Each of the areas could operate independently of the others. Figure 16 illustrates this example. Both the John Hancock Center and Water Tower Place use modifications of the sky lobby concept. The John Hancock Center has a lobby on the 44th and 45th floors for the apartments, but all of the elevators start from the ground floor rather than this lobby. Water Tower Place has a hotel lobby on the 12th floor, but again all elevators start from the base of the building.

A second elevator system which tall buildings as well as multi-use buildings can use advantageously is the double deck elevator. Two major benefits from their use are energy savings and space savings. Double deck elevators assist in saving energy because two floors can be served in one stop. Since double deck elevators can serve two floors at a time, fewer elevator shafts are required. The available floor area on each story will be increased due to the reduction of elevator space (Council on Tall Buildings, 1980). The Citicorp Building is one multi-use building which incorporates double deck elevators. Figure 15 shows a possible double deck elevator system.

6. PSYCHOLOGICAL ASPECTS

As mentioned before, most buildings house only one use. Many of these single use buildings were cold, austere boxes which were not designed for people (Okamoto, 1981). Occupants were very uncomfortable in these surroundings. They wanted buildings in which the environment was more attractive and pleasant (Codella, 1973).

Today designers are attempting to adapt buildings to meet more fully the needs of the occupants. Multi-use buildings are an avenue of achieving a more suitable environment. The following three studies bring out people's reactions to the building environment.

One study was performed at the Chicago Circle campus of the University of Illinois (Simon, 1977). It dealt with economic, environmental, political, social, and technological impacts on users, nonusers, developers, and planners of two highrise buildings in Chicago. The John Hancock Center was one of these buildings and the other was a residential tower along Lake Shore Drive. Only a preliminary report of the study was obtained. However, some interesting findings about the John Hancock Center were introduced. One important fact was that people seemed to like the multi-use concept because it gave them the opportunity to be very close to shops and stores. Residents saw few disadvantages with the building. It is important to note, though, that these people were well-to-do and could choose the type and location of their residences. Other items considered adequate by the users were the police, fire protection and the security system.

A second study was performed at the Georgia Institute of Technology (Young, 1977). It was an evaluation of user needs in

Colony Square in Atlanta after a period of occupancy. Colony Square is a multi-building development rather than a single building, but many functions are similar to those in multi-use buildings. It is because of these similarities that this study is included. This group of buildings contains approximately 800,000 square feet of office space, 460,000 square feet of apartments, a 500,000 square foot hotel, 500,000 square feet of commercial services, and 690,000 square feet of parking. Again, only early findings were obtained, but the major finding was that 94% of the transient users felt the multi-function system was a good idea. Four out of five users said they would use the facilities again. These early findings do not contain the permanent resident's feelings, however.

A third study deals with tall buildings in general (Haber, 1977). The study was performed at the University of Maryland. Three hundred students of varied background were asked what they liked most and what they liked least about tall buildings.

The first four items listed in the favorable category were the view, the ability to see long distances, economical use of space, and convenience to stores (Haber, 1977). Multi-use buildings tend to accentuate many of these positive items. Apartments and hotels located on the upper floors take advantage of the distant views. Multiple use buildings can be economical of space because they include many diverse uses in one site. The incorporation of shops and stores into multi-use buildings is a positive response to the need for amenities.

One area of multi-use buildings in which more research is needed is on the psychological aspects of people living and working in the same building. It is understood that few people who work in these buildings also have their residence in the same structure.

7. CASE STUDIES

Case studies of three noted multi-use buildings will now be presented: The John Hancock Center, Water Tower Place, and the Citicorp Center.

7.1 JOHN HANCOCK CENTER

The John Hancock Center in Chicago is possibly the most prestigious building in the multi-use field. It was designed by Skidmore, Owings, and Merrill. The construction was completed in 1970. The owner is the John Hancock Life Insurance Company. The building is shown in Fig. 1.

Standing at 1107 feet, the Hancock Tower is the fifth tallest building in the world. Twin radio and television towers on the roof bring the total height to 1456 feet. The 100-story building is the tallest multi-use building in the world.

Four different functions are contained within the John Hancock Center. Approximately 1,000,000 sq. ft. of office space is provided. Seven hundred and five apartments utilize 1,000,000 sq. ft. of space. Commercial and parking areas take up 800,000 sq. ft. in the lower floors. Each facility has a different entrance. Figure 14 gives the layout of the different uses (Iyengar, 1973).

The John Hancock Center is easily identifiable both by its unique shape and by the huge steel X's on the sides. (The building has an area of 50,000 sq. ft. at the base and tapers to only 16,000 sq. ft. at the top.) The X's are the bracing of the diagonalized tube structure used in the building. This structural system allowed the building to be constructed at the per square-foot cost of a traditional forty story building. The total frame consists of 46,000 tons of steel (John Hancock, 1970).

By cutting through the walls at forty-five degree angles, the X's create many interesting views from the apartments. The windows are located twenty inches from the floor to provide optimal views (Bacigalupo).

The John Hancock Center is an all-electric building. It contains 1250 miles of wiring, five escalators, and fifty elevators. When the building was completed in 1968, the three express elevators to the observatory were the world's fastest.

The twin 349-foot towers on the roof have the capability of handling up to ten television stations, twenty FM radio stations, and seventy-three shortwave and microwave units.

The multi-use concept in the John Hancock Center has been quite successful. The various functions allow a twenty-four hour use of the land rather than a typical twelve hour use in office buildings. The success of this structure in the late 1960's was very important because it encouraged the growth of many similar projects in that area of Chicago (Khan and El Nimeiri, 1982).

7.2 WATER TOWER PLACE

The 859-foot Water Tower Place, completed in 1975, is the world's tallest concrete building. Its designers were Loebl, Schlossman, Bennett & Dart, and C. F. Murphy Associates. The co-owners are Mafco, Inc., a subsidiary of Marshall Field & Company, and the Urban Investment and Development Company, a subsidiary of Aetna Life & Casualty. The building, shown in Fig. 3, takes its name from the old

Chicago Water Tower across the street which survived the great Chicago Fire of 1871.

The seventy-six story building has four uses. The twelve story base contains commercial areas and offices. A hotel and condominiums are in the 64-story tower. These functions cover a total of 3.1 million square feet. Figure 17 shows the layout of the various functions.

The lower seven floors cover 750,000 sq. ft. These floors house more than 100 stores and restaurants. A seven-story grand atrium, complete with waterfalls and greenery, and five two-story mini-atriums are also in this section. Located in this same area is a a 1200-seat theater in the round (Chicago Tribune, 1975).

Office space and the environmental control system of the building occupy floors eight through eleven.

The Ritz-Carlton Hotel occupies twenty-two floors starting with an elegant sky lobby on the twelfth floor. The 450 room hotel offers a rooftop garden and a bar in its greenhouse (Water Tower Place).

Two hundred and sixty condominiums occupy the forty floors above the hotel. When the condominiums first went on sale in 1975, prices ranged from $137,000 to $257,000. Duplexes which included a spiral staircase were available for $180,000 (Chicago Tribune, 1975).

Water Tower Place is another successful multi-use structure. This building, along with the John Hancock Center and One Magnificent Mile (when completed), help keep Chicago's Gold Coast alive at all hours.

7.3 CITICORP CENTER

At 915 feet, the Citicorp Center was the ninth tallest building in the world when it was completed in 1977. The architects for the project were Hugh Stubbins & Associates and Emery Roth & Sons. The structural engineers were LeMessurier Associates and The Office of James Ruderman. The 59-story building, owned by Citicorp, is shown in Fig. 2.

Contained in the Center are offices and an international marketplace. A church sits on one corner of the site, but is not an integral part of the building. An atrium and a landscaped sunken plaza are also included.

The office tower is supported on four, 127-foot stilts. Six thousand people, working for many different firms, utilize the one million square feet of office space contained in the building. This tower employs many modern energy saving features. The building has twice the usual insulation and only 46% of the outside walls is glass. A lighting system is used which reduces wattage by 50%. Dual computers are used by the building's management system to moniter all HVAC and security systems. The crown is sloped at forty-five degrees to the south so solar energy can be installed when the technology becomes economical. Also in the crown is a tuned mass damper. It is a 400-ton concrete block which counteracts movement and reduces the peak acceleration of the building by 40% (ENR, 1977).

The international marketplace is contained in the seven-story low-rise section of the building. It contains twenty-four shops and restaurants, plus twenty-four hour banking and other features. The elevators which take people into the tower are in this area (Citicorp Center).

St. Peter's Lutheran Church occupies the northwest corner of the site. Extensive programs in education, music, art, and other areas are carried out by the church for the community.

Horizontal and vertical loads in the building are carried by exterior diagonal bracing. The structural system employed resulted in a steel weight of only twenty-two pounds per square foot. Figure 18 shows a simplified version of the system (ENR, 1976).

The Citicorp Center has had major impact on New York. As Goldberg states (1981):

> "It was not daringly new by any means, but it did sum up the best developments of the time: it was visually smooth and cool, though here the coolness was that of a softly glowing white aluminum and not of glass; it had a street level devoted to public uses, in this case a set of stores and restaurants around an atrium; and it had a top that was sliced off at a 45-angle degree, giving the building a strong mark on the skyline."

This center is truly, according to a Citicorp Center pamphlet, "a valuable addition to the urban landscape."

8. SUMMARY

Developers, builders, and users are finding that multiple use buildings, which can include apartments, offices, shops, and other functions, can help alleviate many problems which are of concern in urban areas. Multi-use buildings help rejuvinate downtown areas, conserve energy, prevent crime, eliminate city canyons, and reduce overcrowding on sidewalks.

The multiple use concept in tall buildings has seen significant growth since the early 1960's. To date, 81 multi-use buildings have been identified in the United States. As Fig. 4 shows, this number is increasing rapidly. The percentage of multi-use buildings is also increasing, both nationally and internationally.

The structure which houses a multi-use building is called a megastructure. In most multiple use buildings the megastructure has been steel or concrete. A few have been built with a combination of materials, and research is underway to examine the possibility of using masonry.

The multiple uses of a building can affect its structural system. Factors discussed in this paper, such as spandrel beam shape, floor-to-floor height, and interior column spacing are subsystems that are so affected.

Innovative architectural concepts such as atriums and unique floor plans are incorporated into multi-use buildings. New elevator characteristics like double deck elevators and sky lobbies are also used.

A few studies have been performed on users of multiple use buildings. The results from the studies indicate users are generally satisfied. One frequently mentioned problem, though, is the expense.

Specific information is included in this paper on three noted multiple use buildings: the John Hancock Center, Water Tower Place, and the Citicorp Center.

Overall, the outlook for multi-use buildings is very favorable. Many new multiple use buildings are being constructed, and hopefully these buildings will help improve the quality of life for everyone.

9. GLOSSARY

City Canyon - See Vertical Canyon

Cladding - The covering or overlay on the outside surface of a building

Damping - The dissipation of energy for dynamic loading

Double-deck elevator - A double cavity elevator serving equally spaced landings so that both cavities can be simultaneously loaded or unloaded

Elevator - A passenger of freight classification of vertical transportation for the movement of passengers or freight with an operator between floors

Erection - The assemblage of structural elements into an integrated structural system

Megastructure - The structure which houses a multi-use building

Mixed Construction - Using two or more construction materials in the structure of a building

Multi-building Development - A group of buildings developed at the same time and usually providing for various functions

Multi-use Building - A single building incorporating multiple functions

Shuttle elevator - An express elevator between two landings to transport pedestrian traffic from the street lobby to a sky lobby above

Single occupancy - A classification of office building occupancy; a building with only one primary use

Sky Lobby - A major lobby above the street to permit transfer from a bank of express shuttle elevators to a bank or banks of local elevators

Spandrel - In skeleton frame buildings, the panel of wall between adjacent structural columns and between the windowsill and the window head next below it

Urban Activity Centers - See Multi-building Development

Vertical Canyon - A canyon at street level in urban areas formed by block after block of bulky, tall buildings

TABLE 1. MULTI-USE BUILDINGS IN THE UNITED STATES

BUILDING	CITY	YEAR	MATERIAL
Acadamy House	Philadelphia		
American Bank	Baton Rouge	1976	
American Building	Dayton	1932	mixed
Auditorium Theater	Chicago	1889	
Biltmore Tower	Dayton	1928	conc.
Brooks Exec. Tower	Denver	U.C.	conc.
Carew Tower	Cincinnati	1932	steel
Celestial Apts	Cincinnati	1967	steel
Central Bank	Birmingham		conc.
Centre City Bldg	Dayton	1927	conc.
Centre Square	Philadelphia	1973	conc.
Century Center	Honolulu	1978	conc.
Citicorp Center	New York	1977	steel
City County Building	Detroit	1953	steel
City Center Complex	Denver		
Cliff Towers	Dallas	1927	masonry
Clinical Sciences	Tucson	1971	conc.
El Paso Natl Bank	El Paso	1961	steel
Equitable Bank Centre	Baltimore	1979	steel
Financial Plaza	Honolulu	1969	conc.
First Alabama Bank	Birmingham		steel
1st Natl Bank Oregon	Portland	1972	steel
1st Natl Southern Nat	Birmingham		steel
Fourth Natl Bank	Cincinnati	1905	steel
Fox Plaza	San Francisco		steel
Franklin Plaza	Philadelphia	1980	steel
Galaxy Complex	Guttenburg	1976	steel
Galleria	New York	1976	conc.
Great Western Plaza	Phoenix	1980	steel
Hall of Justice	Columbus	1972	steel
Harbor Square	Honolulu	1971	conc.
Hartford Sq North	Hartford		
Hilton Inn/Garage	Seattle	1971	
Ilikai Apts.	Honolulu	1963	conc.
Ind Valley Bank	Philadelphia	1969	conc.
Int River Center	New Orleans	1977	steel
Jackson Co C.H.	Kansas City, Mo	1933	steel
John Hancock Center	Chicago	1968	steel
Kaiser Building	Oakland		steel
Lafayette Centre	Washington, D.C.		
Lawrence Hall	Pittsburgh	1927	steel
Lewis Tower	Philadelphia		
Life Building	Dallas	1951	mixed
Louisiana Nat. Bank	Baton Rouge	1968	
Manor House	Dallas	1966	masonry
Marina City	Chicago	1962	conc.
Medical Tower	Philadelphia		

Mer Plaza/Reg Hyatt	Indianapolis	1977	
Michigan & Oak	Chicago	1981	conc.
Midtown Tower	Rochester	1962	steel
Millender Center	Detroit		
Neiman-Marcus	Chicago	1981	conc.
No. 3 Park Ave	New York	1975	conc.
Olympic Tower	New York	1975	mixed
Omni Hotel	Atlanta	1977	steel
One Magnificent Mile	Chicago	1983	conc.
Pacific Building	Seattle	1969	
Pacific Ins Co Bldg	San Francisco	1972	conc.
Phil Sav Fund Soc	Philadelphia	1932	steel
Phoenix Center	Phoenix	1979	conc.
Pittsfield Bldg.	Chicago	1927	steel
Post Times	Cincinnati	1931	conc.
Power	Cincinnati		
Price Tower	Bartlesville	1956	
Railway Exchange	St. Louis	1912	steel
Reunion Center	Dallas	1978	mixed
S.W. Bell Telephone	Dallas	1927	conc.
State Natl Bank	El Paso	1971	steel
Talbott Tower	Dayton	1958	mixed
Terminal Tower	Cleveland	1930	steel
Thirty-Three	New York		
Toledo Trust Bldg	Toledo	1915	steel
Townhouse Hotel	Phoenix	1964	conc.
Union Bank	Bethlehem	1967	steel
United Bank Center	Denver	1984	
United Nations	New York	1952	
Villa On Eaton Sq.	Honolulu	1974	conc.
Water Tower Place	Chicago	1976	conc.
Winters Bank Tower	Dayton	1970	steel
YMCA Building	Dayton	1929	conc.
1500 Locust Street	Philadelphia	1973	conc.

Sources: High Rise Building Data Base (Council on Tall Buildings)
Independent Research

TABLE 2. MULTI-USE BUILDINGS INTERNATIONALLY

BUILDING	CITY	COUNTRY	YEAR
A2,A3 G.Lazar Str.	Timisoara	Romania	1973
Administration Bldg	Pleven	Bulgaria	1978
Ang House	Port Moresby	New Guinea	1967
Angkasa Raya	Kuala Lumpur	Malaysia	U.C.
Anson Centre	Singapore	Singapore	1971
Apartment House	Vratsa	Bulgaria	1970
Apartment Houses	Samokov	Bulgaria	1977
Apartmant Houses (2)	Mihajlovgrad	Bulgaria	1976
Apartment Houses (2)	Mihajlovgrad	Bulgaria	1976
Apartment Houses (2)	Pazardjik	Bulgaria	1971
Apartment Houses (5)	Jambol	Bulgaria	1971
Apt. Houses/Shops (4)	Kardjali	Bulgaria	1977
Apollo Hotel	Singapore	Singapore	1972
Australia Square	Sydney	Australia	1968
Assurances Generales	Brussels	Belgium	1961
Bangalore Mun. Corp.	Bangalore	India	
Belmont Centre	Kuala Lumpur	Malaysia	U.C.
Bouw Center	Rotterdam	Netherlands	1971
Bldg Public Organization	Belgrade	Yugoslavia	1974
C5 Giroc Way	Timisoara	Romania	1976
Cacique	Porto Alegre	Brazil	1960
Calero	Guayaquil	Ecuador	1950
Causeway Center	Hong Kong	Hong Kong	
Central Square	Sydney	Australia	1972
Cleopatra	Cairo	Egypt	1960
Collins Place-AMP Tower	Melboure	Australia	U.C.
Commercial/Service Bldg	Blagoevgrad	Bulgaria	1970
Crawford Tower	Singapore	Singapore	1974
Deba Westendistr.	Munich	W. Germany	1973
Deepak Estate	Hyderabad	India	
Dubai Int Trade Center	Dubai	U.Arab Emi.	1978
Dusit Thanee Hotel & Off	Bangkok	Thailand	
Edificio Andraus	Sao Paulo	Brazil	
Ed. Boa Esperanca	Belo Horizonte	Brazil	1960
Edificio Espana	Madrid	Spain	1952
Edif. Excelsior	Santos	Brazil	1970
Edif. Pedro 2	Santos	Brazil	1970
Electromotor Bldg	Timisoara	Romania	1975
Esq la Colmena Y Wilson	Lima	Peru	1958
Forum Royal	Luxembourg	Luxembourg	1977
Frolundatore	Gothenburg	Sweden	1967
Fukuoka DNT Bldg	Fukuoka	Japan	1976
Gagan Vihar	Hyderabad	India	
Galeria Do Rosario	Porto Alegre	Brazil	1970
Gebouw Werktuigbouw Tech	Enschede	Netherlands	1968
Golden Mile Shopping Cen	Singapore	Singapore	1972
Golden Mile Tower	Singapore	Singapore	1974

Govt. Off. Conf. Hall	Nairobi	Kenya	1972
Gran Passaje	Guayaquil	Ecuador	1969
Granda Centeno	Quito	Ecuador	1973
Harihisa Building	Sendai	Japan	
High Street Center	Singapore	Singapore	1974
Hilton Hotel	Singapore	Singapore	1969
Himalaya House	New Delhi	India	1970
Hong Leong Bldg	Singapore	Singapore	1976
Hotel	Jambol	Bulgaria	1969
Hotel Cherno More	Varna	Bulgaria	1978
Hotel Intercontinental	Dacca	Bangladesh	1965
Hotel International	Varna	Bulgaria	1968
Hotel Miramar	Singapore	Singapore	1970
Hotel Purbani	Dacca	Bangladesh	1965
Hotel Summit	Singapore	Singapore	1971
Hyatt Hotel	Singapore	Singapore	1971
Imperial Oil	Edmonton	Canada	1970
Indra Regent Hotel	Bangkok	Thailand	
International Bldg	Hong Kong	Hong Kong	1967
International Plaza	Singapore	Singapore	1976
Iwasaki Gakvew	Yokohama	Japan	1973
Iwasaki Gakvew (Mit.)	Yokohama	Japan	1973
Jerez Housing	Jerez	Spain	1977
Jetro	Bangkok	Thailand	
Kauak	Osorno	Chile	
Kings Hotel	Singapore	Singapore	1970
KMC Super Market	Karachi	Pakistan	1976
Kredietbank	Luxembourg	Luxembourg	1977
K.V.Kronprinsen	Malmo	Sweden	1964
Le Carrefour	Luxembourg	Luxembourg	U.C.
Lentia 2000, A-Block	Linz	Austria	1976
Les Horizons	Rennes	France	1970
Les Poissons	Paris	France	1970
Lyngby Storcenter	Copenhagen	Denmark	1973
Manhattan	Brussels	Belgium	1972
Manhattan House	Singapore	Singapore	1974
Marasti Square	Timisoara	Romania	1973
Marutann	Yokohama	Japan	U.C.
Maxwell House	Singapore	Singapore	1971
Meitetsu Bus Terminal	Nagoya	Japan	1967
Montepio de Mocambique	Lourenco Marque	Portugal	1974
Munincipal Corp.	Bangalore	India	
Nara Fudosan Bldg	Yokohama	Japan	U.C.
Neboticnik	Ljubljana	Yugoslavia	1932
New Alexandria House	Hong Kong	Hong Kong	1978
Nishnippon Watanabe Bldg	Fukuoka	Japan	1975
Nobistor	Hamburg	W. Germany	1972
Normandie	Caracas	Venezuela	1972
Og Building	Singapore	Singapore	1972

Osaka Merch. Mart Bldg	Osaka	Japan	1969
OUB Building	Singapore	Singapore	1974
Park Regis	Sydney	Australia	1969
Parque Cent. Edif Viv.	Caracas	Venezuela	1972
Peace Center	Singapore	Singapore	1974
Pearl City Mansion	Hong Kong	Hong Kong	1971
Peoples Park Center	Singapore	Singapore	1974
Peoples Park Complex	Singapore	Singapore	1973
Piazza Repubblica	Milan	Italy	1957
Pl.Des La Tour du L Est	Montreal	Canada	1976
Pl.Des La Tour du Nord	Montreal	Canada	1976
Pl.Des La Tour du Sud	Montreal	Canada	1976
Realty Building	Hong Kong	Hong Kong	1967
Reed y Reed	Guayaquil	Ecuador	1964
Regal House	Singapore	Singapore	1973
Robina House	Singapore	Singapore	1973
Ryukai Building	Naha	Japan	
Salazar Gomez	Quito	Ecuador	1972
Sannomiya West Bldg	Kobe	Japan	1975
Santa Cruz	Porto Alegre	Brazil	1960
Schwabylon	Munich	W. Germany	1973
Selegie Complex	Singapore	Singapore	1972
Sendai Sakuragaoka Apt	Sendai	Japan	1973
Shell Building	Beirut	Lebanon	1962
Shenton House	Singapore	Singapore	1974
Shenton Plaza	Singapore	Singapore	1974
Shing Kwan House	Singapore	Singapore	1973
Shinnagataeki Apt House	Kobe	Japan	1976
Simpson Tower	Toronto	Canada	1968
Soc Cattolcica di Assic	Naples	Italy	1958
Soviet Trade Center	Moscow	USSR	1978
Student Hostel	Warsaw	Poland	1962
Sun Hing Building	Hong Kong	Hong Kong	1966
Sun Hung Kai Centre	Hong Kong	Hong Kong	1980
Supreme House	Singapore	Singapore	1971
Textile Center	Singapore	Singapore	1974
Theresienhone	Munich	W. Germany	1973
Tokai Bussan Bldg	Yokohama	Japan	U.C.
Tokai Fudohsan Bldg	Yokohama	Japan	U.C.
Toronto Dominion	Regina	Canada	1972
Toronto Dom. Bank Tower	Vancouver	Canada	1970
Torre de Madrid	Madrid	Spain	1950
Torre Velasca	Milan	Italy	1958
Torres de la Colon	Quito	Ecuador	1972
Tour D'ivoire	Montreux	Switzerland	1962
Tour Residence	Morges	Switzerland	1969
Tower of Madrid	Madrid	Spain	1960
TV	Bratislava	Czech.	1974
UMBC Building	Kuala Lumpur	Malaysia	1973

Wisma M P I	Kuala Lumpur	Malaysia	U.C.
Wisman Stephens Bldg	Kuala Lumpur	Malaysia	U.C.
Wohnhochhaus Leipziger	Berlin	E. Germany	
Wohnhaus Spandauer Str	Berlin	E. Germany	1970
Wu Sang House	Hong Kong	Hong Kong	1966
47 Circum. Zone	Timisoara	Romania	1974
5,1 December Street	Timisoara	Romania	1975

Sources: High Rise Building Data Base (Council on Tall Buildings)
Independent Research

TABLE 3. USES OF TALL BUILDINGS IN THE UNITED STATES

Building Use	Number of Buildings	Percentage of Total
Apartments	169	14.8
Business (a)	7	0.6
Church	0	0.0
Dormitory	34	3.0
Government	3	0.3
Hospital	31	2.7
Hotel/Motel	131	11.5
Ind./Manu.	0	0.0
Laboratory	2	0.2
Library	1	0.1
Miscellaneous (b)	2	0.2
Multi-use	69	6.0
Museum	1	0.1
Office	676	59.2
Parking	0	0.0
Recreational (c)	3	0.3
Residential	4	0.4
School	5	0.4
Store/Retail	4	0.4
Theater	0	0.0
Warehouse	0	0.0
Total	1142	

a. Business includes: banks, a telephone exchange, and telecommunications buildings
b. Miscellaneous includes: clock towers, monuments, and a mausoleum
c. Recreational includes: a club, athletics, arcade, and stadiums

Source: High Rise Building Data Base (Council on Tall Buildings)

TABLE 4. USES OF TALL BUILDINGS INTERNATIONALLY

Building Use	Number of Buildings (a)	Percentage of Total
Apartments	468	28.3
Business (b)	15	0.9
Church	4	0.2
Dormitory	3	0.2
Government	2	0.1
Hospital	28	1.7
Hotel/Motel	197	11.9
Ind./Manu.	4	0.2
Laboratory	2	0.1
Library	2	0.1
Miscellaneous (c)	6	0.4
Multi-use	152	9.2
Museum	2	0.1
Office	725	43.8
Parking	2	0.1
Recreational (d)	4	0.2
Residential	13	0.8
School	21	1.3
Store/Retail	3	0.2
Theater	1	0.1
Warehouse	1	0.1
Total	1655	

a. Excludes United States
b. Business includes: banks, a telephone exchange, and telecommunications buildings
c. Miscellaneous includes: clock towers, monuments, and a mausoleum
d. Recreational includes: a club, athletics, arcade, stadiums, and sport/fest

Source: High Rise Building Data Base (Council on Tall Buildings)

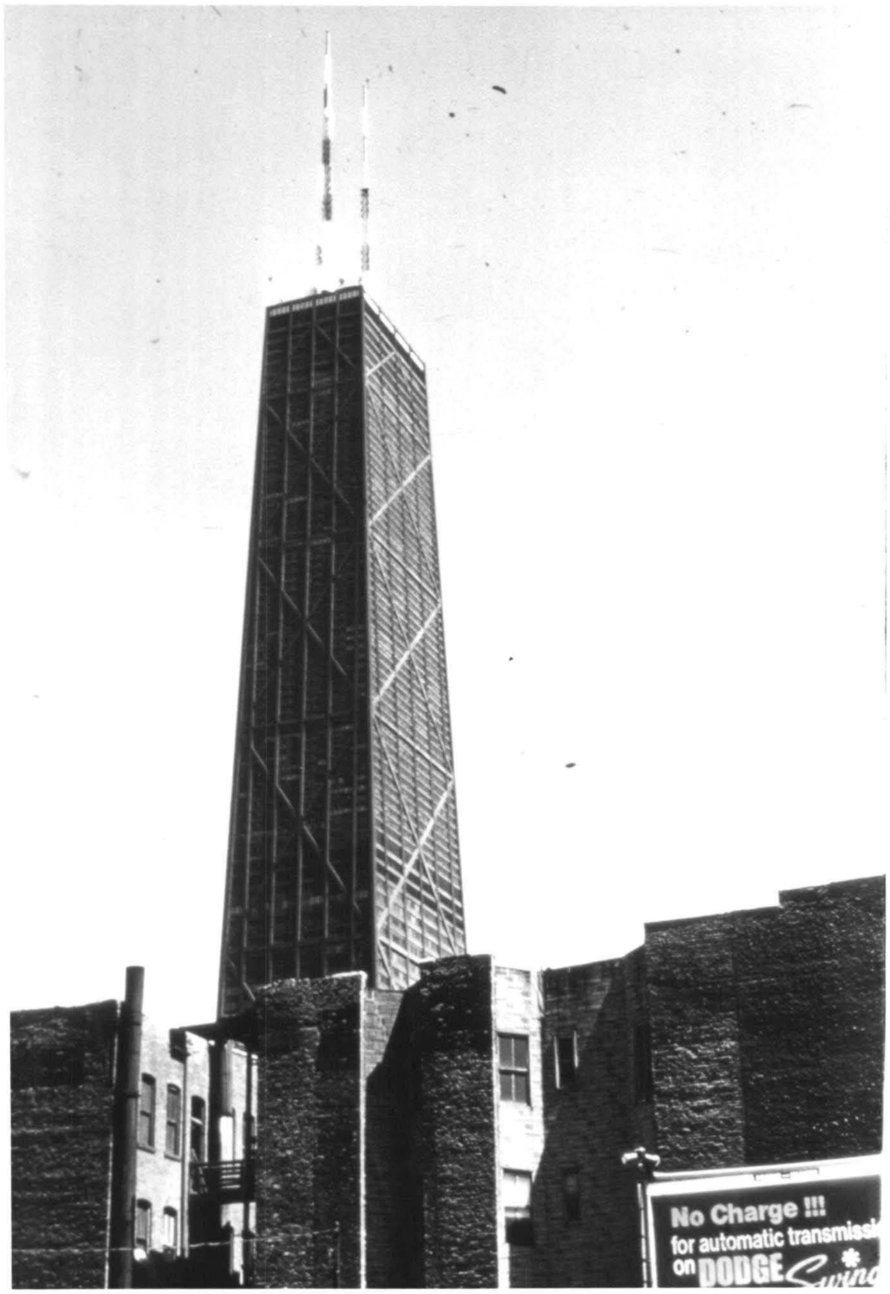

Figure 1: The John Hancock Center in Chicago
(Photo Credit: Richard Torrens)

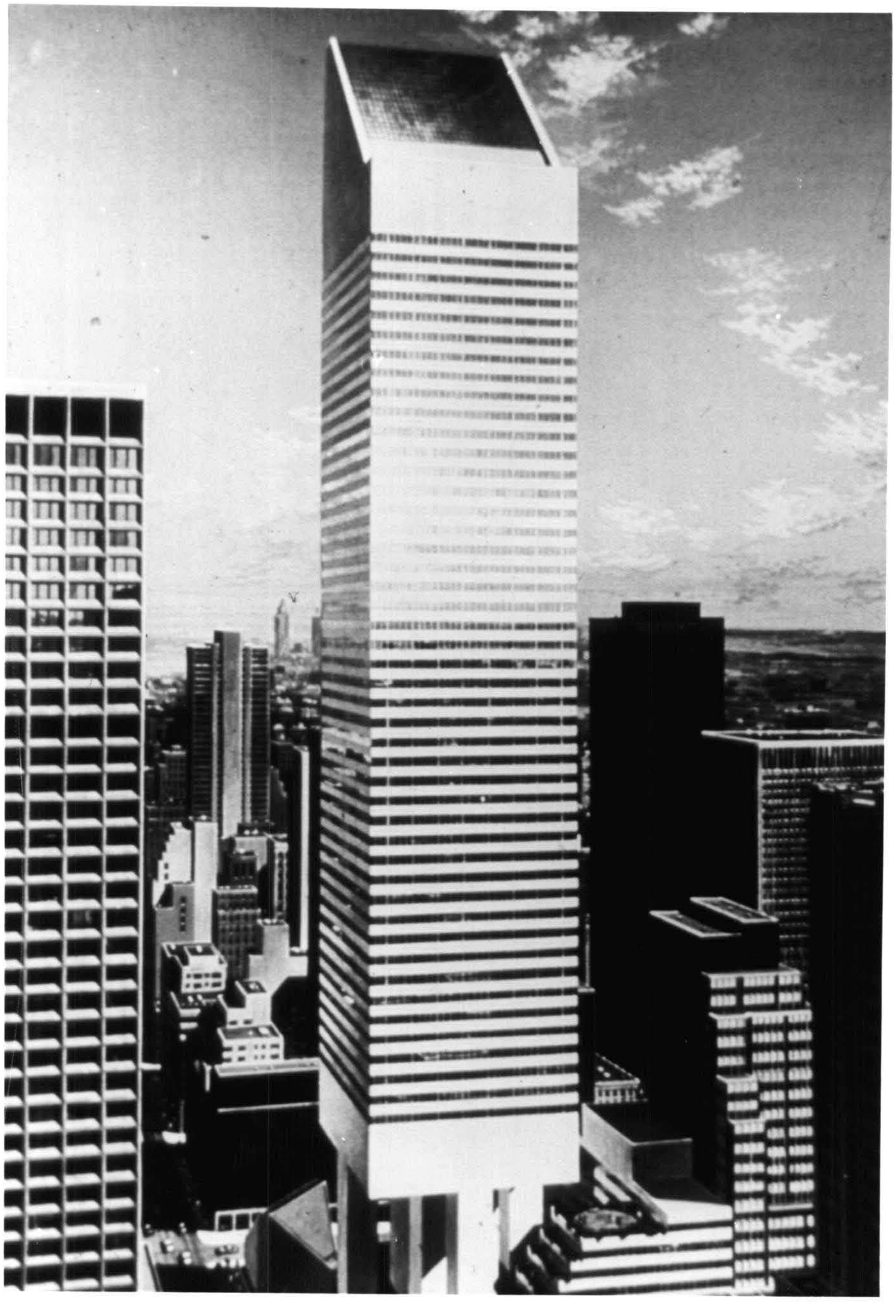

Figure 2: The Citicorp Center in New York
(Photo Credit: Citicorp Center)

Figure 3: Water Tower Place in Chicago
(Photo Credit: ENR, 1975)

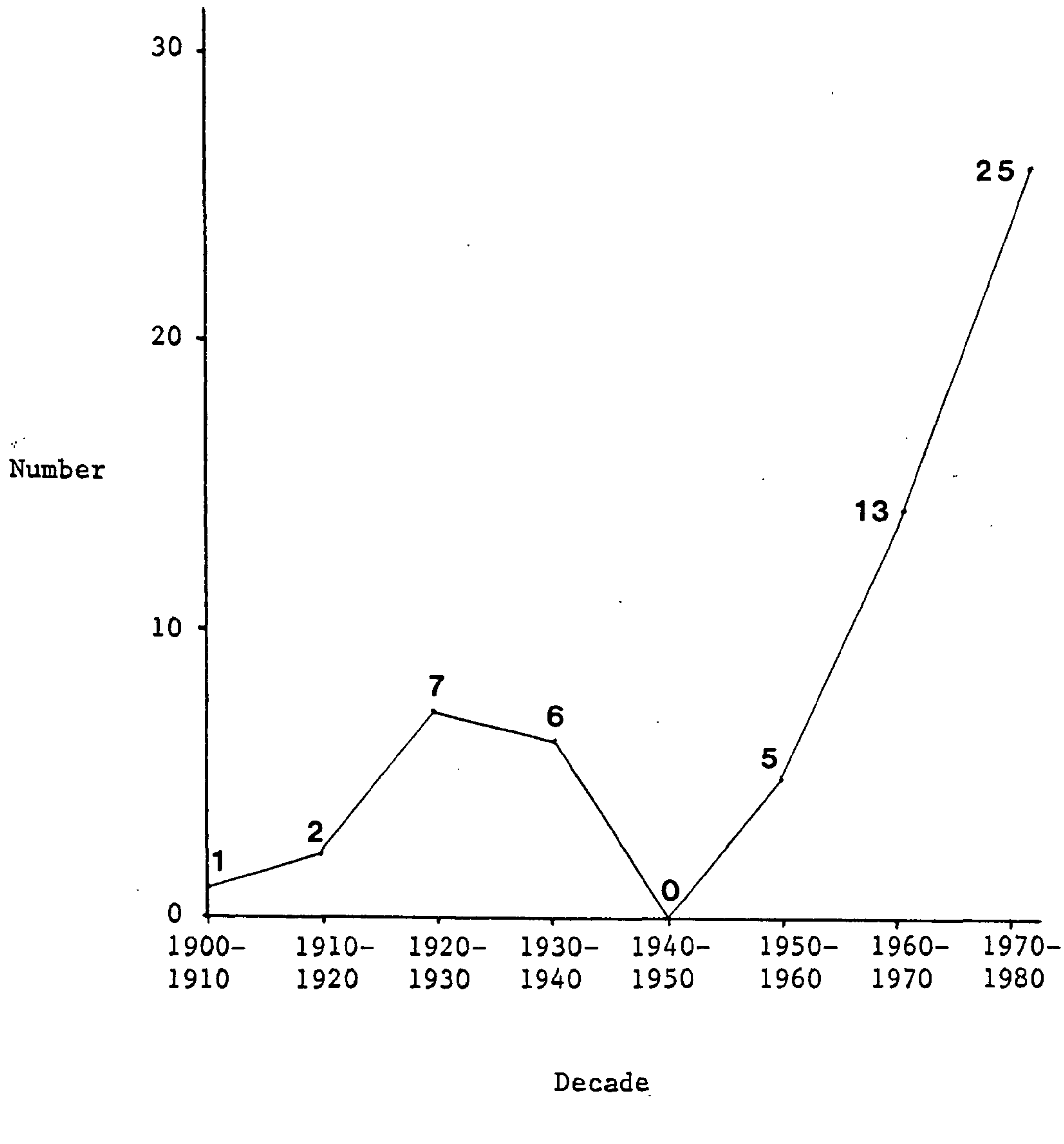

Figure 4: Multi-use Structures built per decade in U.S.

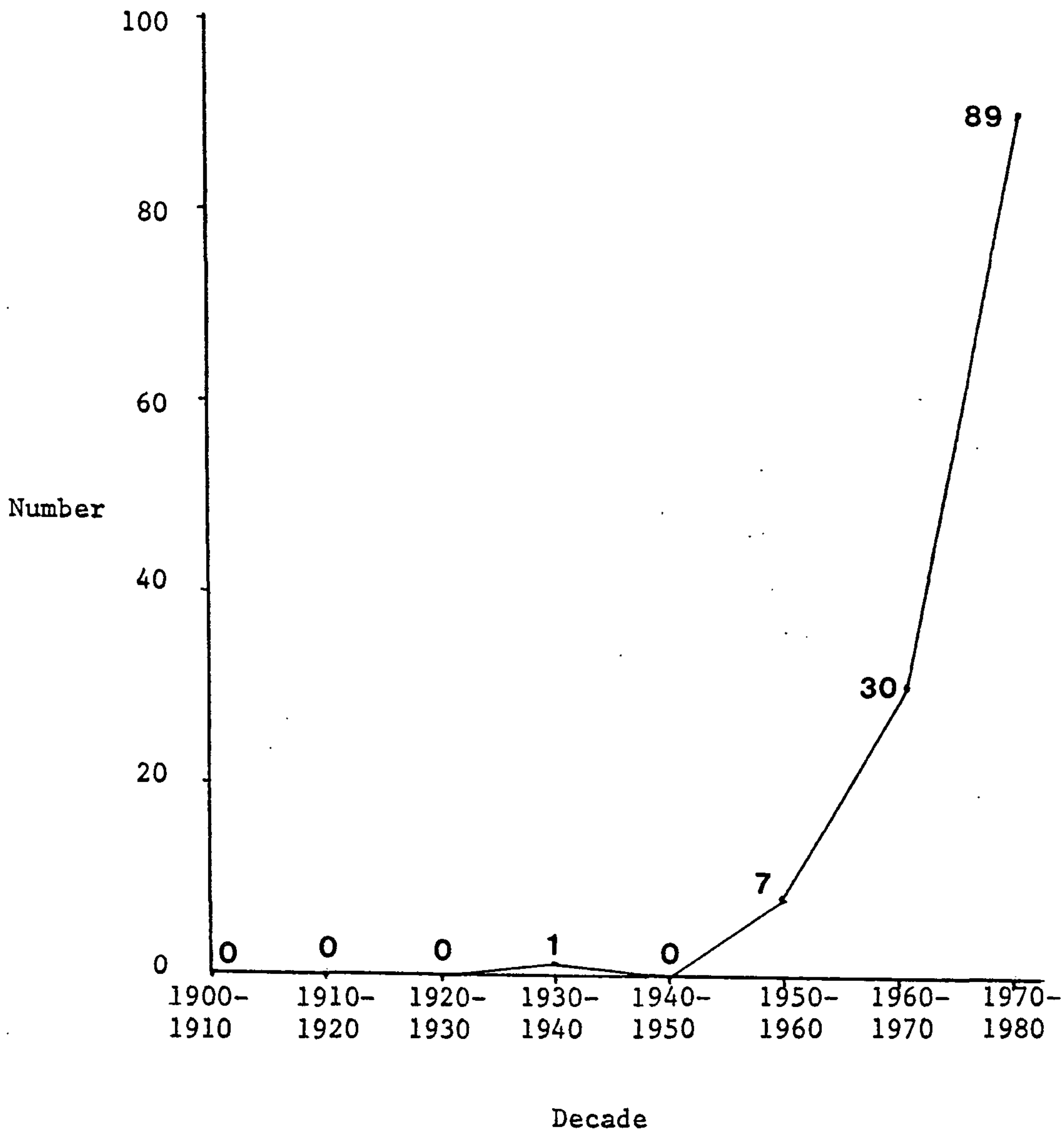

Figure 5: Multi-use structures built per decade in world

Figure 6: The Marina Towers in Chicago
(Photo Credit: Dudley, Hardin, & Yang, Inc.)

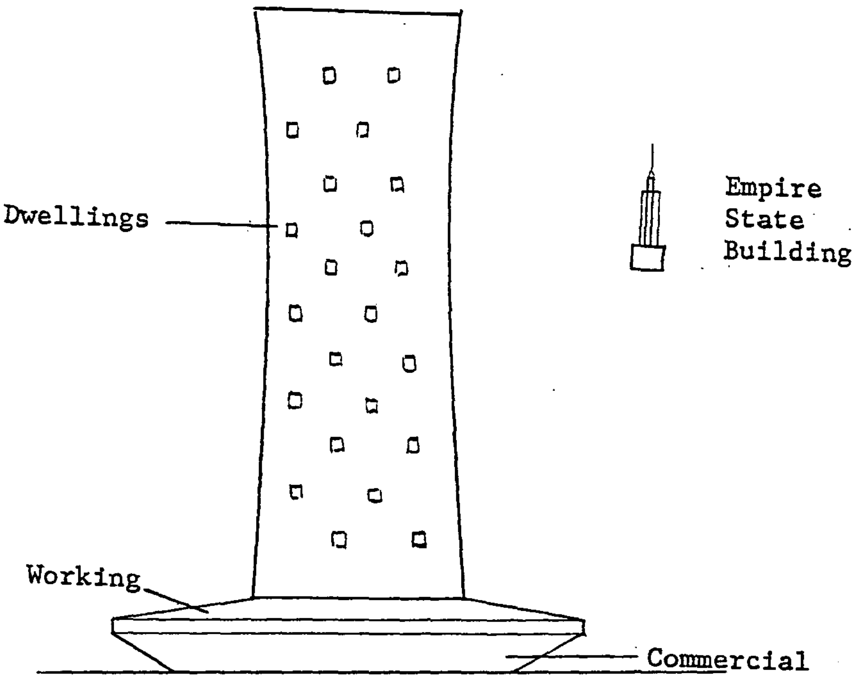

Figure 7: Paulo Soleri's mile-high structure

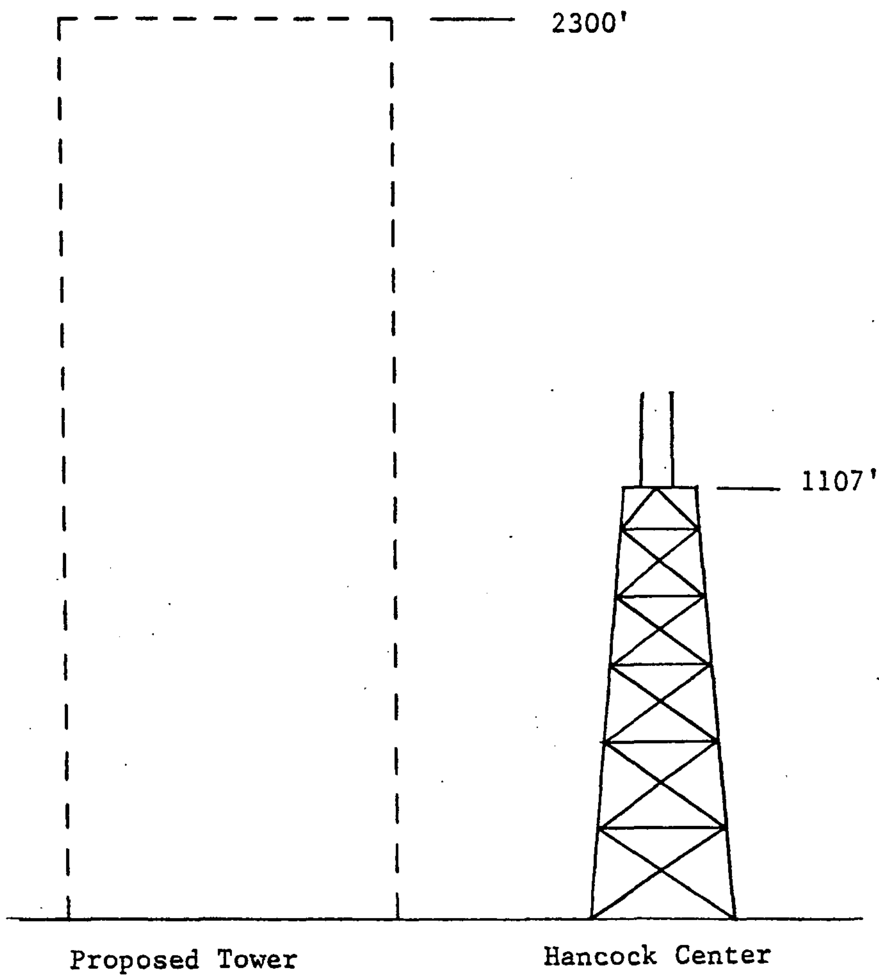

Figure 8: Height comparison of multi-use structures

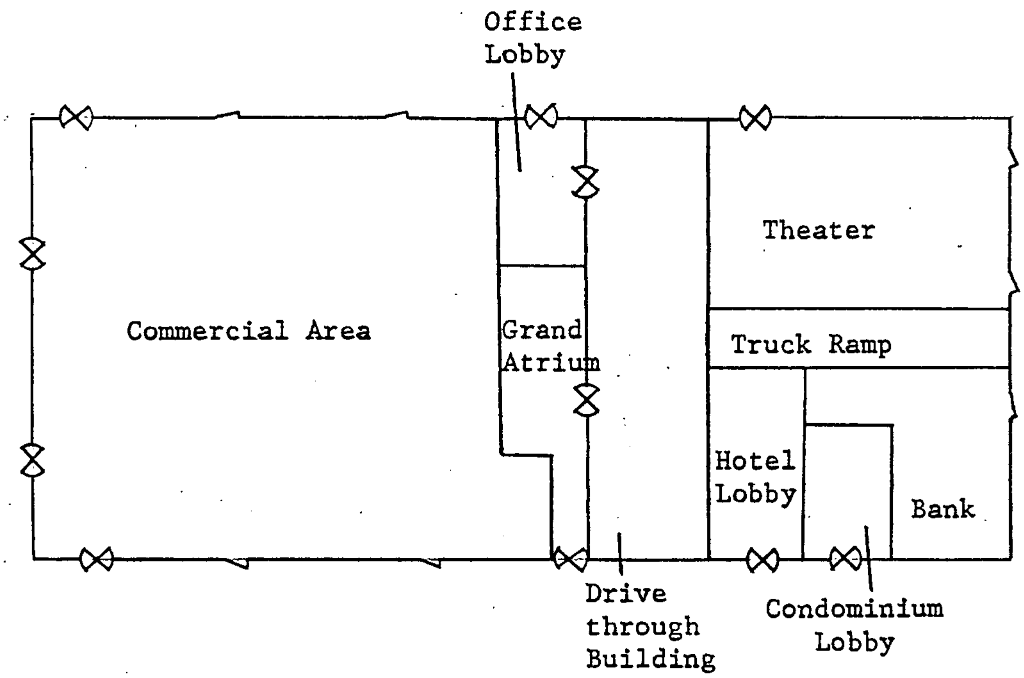

Figure 9: Ground floor plan of Water Tower Place

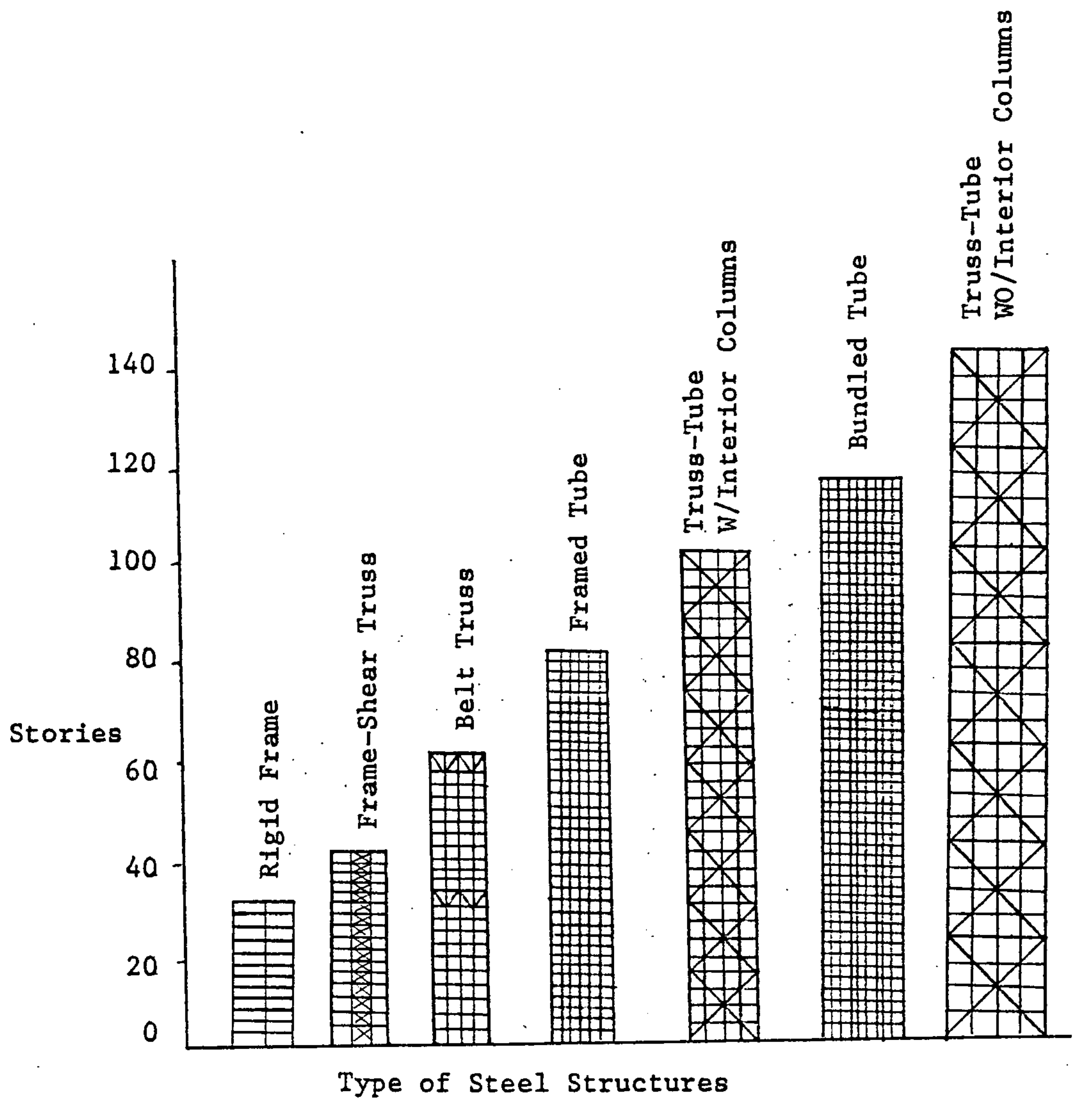

Figure 10: Seven basic steel structural systems
(Source: Khan, 1973)

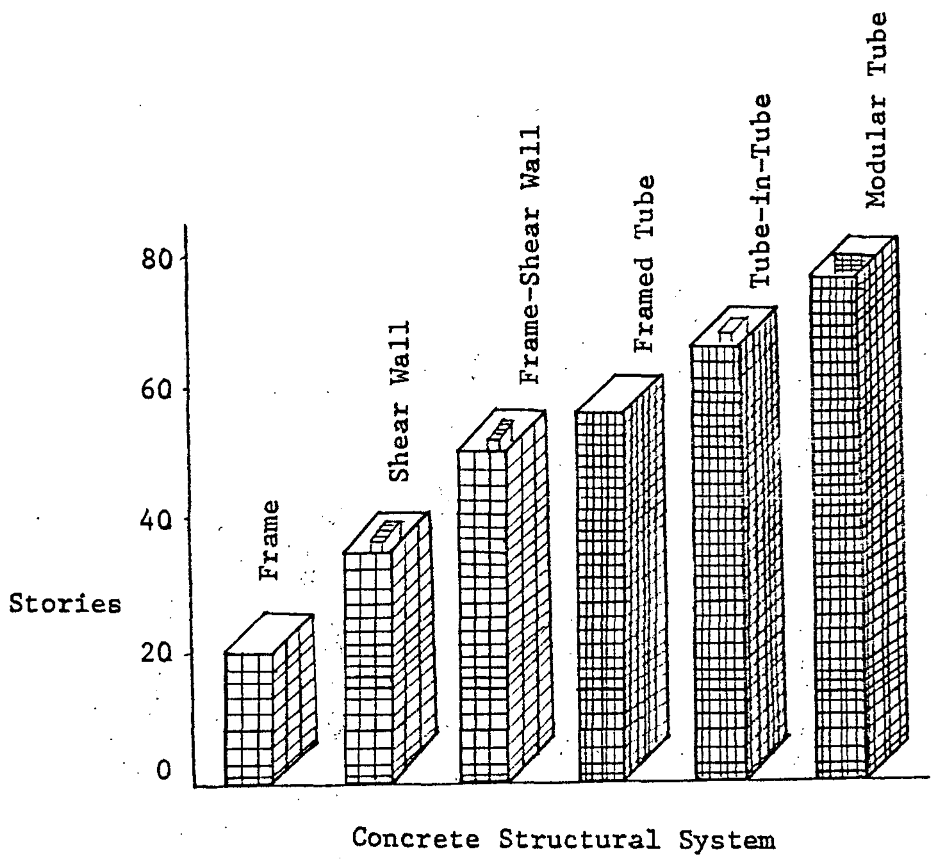

Figure 11: Six basic concrete structural systems
(Source: Khan, 1973)

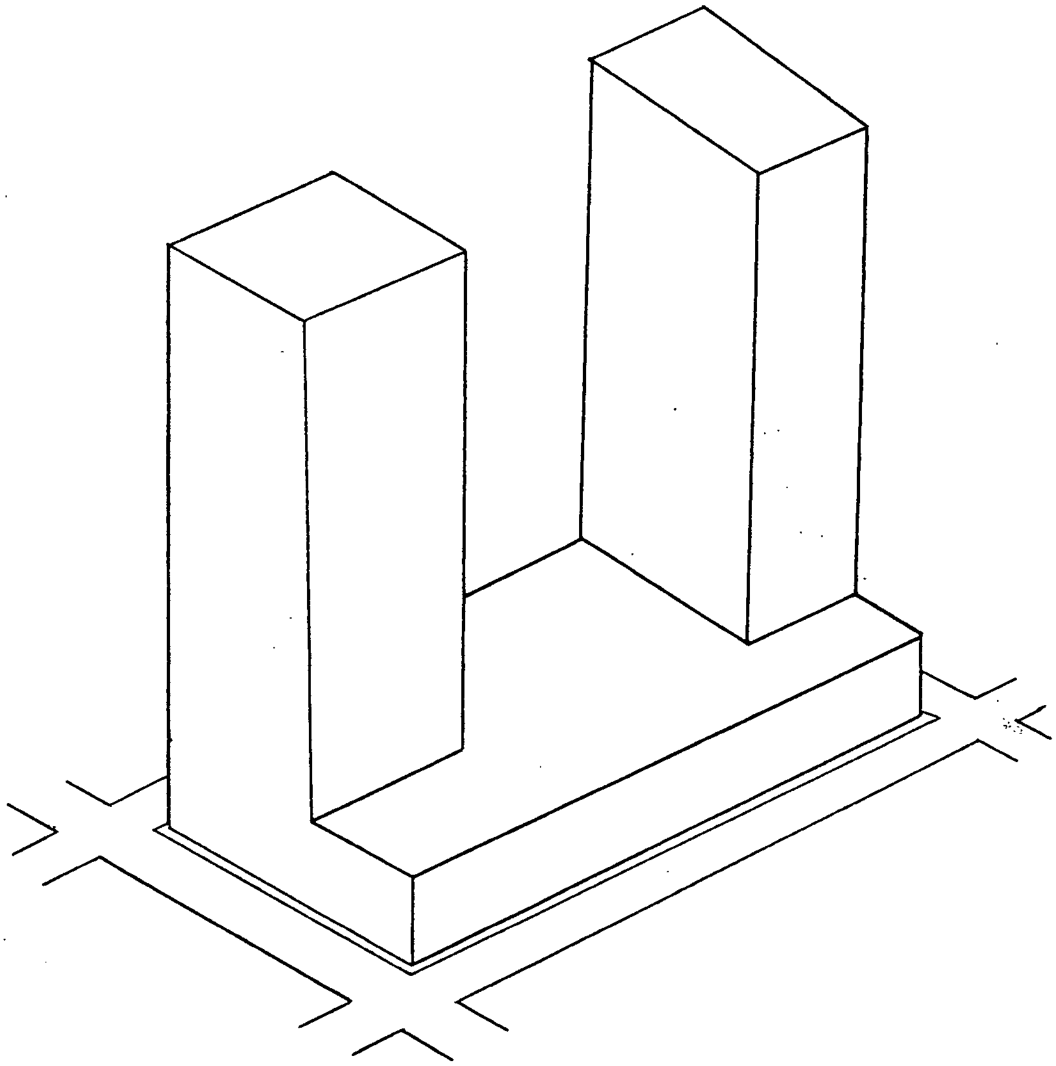

Figure 12: Initial plan for the Hancock Center
(Source: Khan, 1974b)

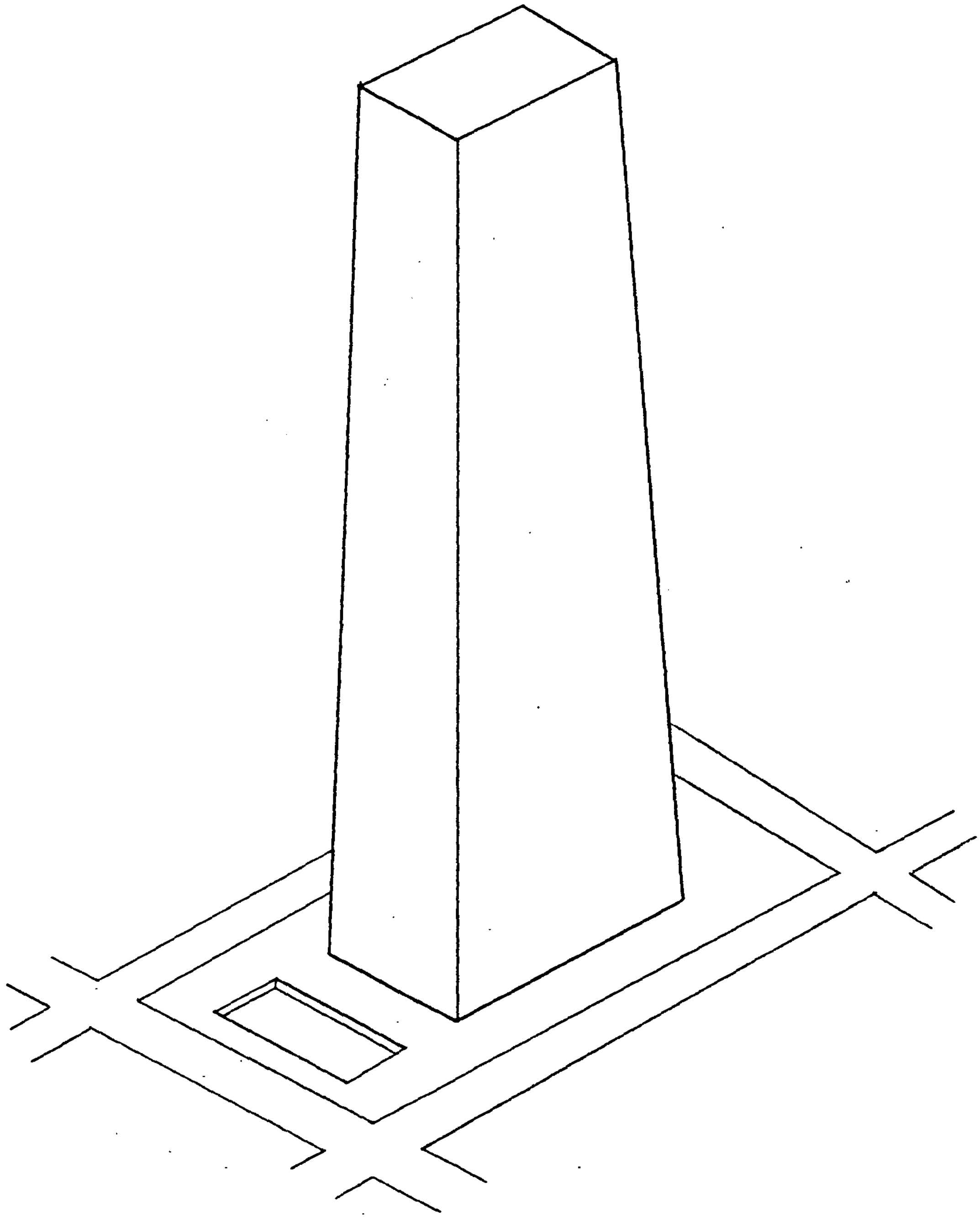

Figure 13: Final Hancock Center design
(Source: Khan, 1974b)

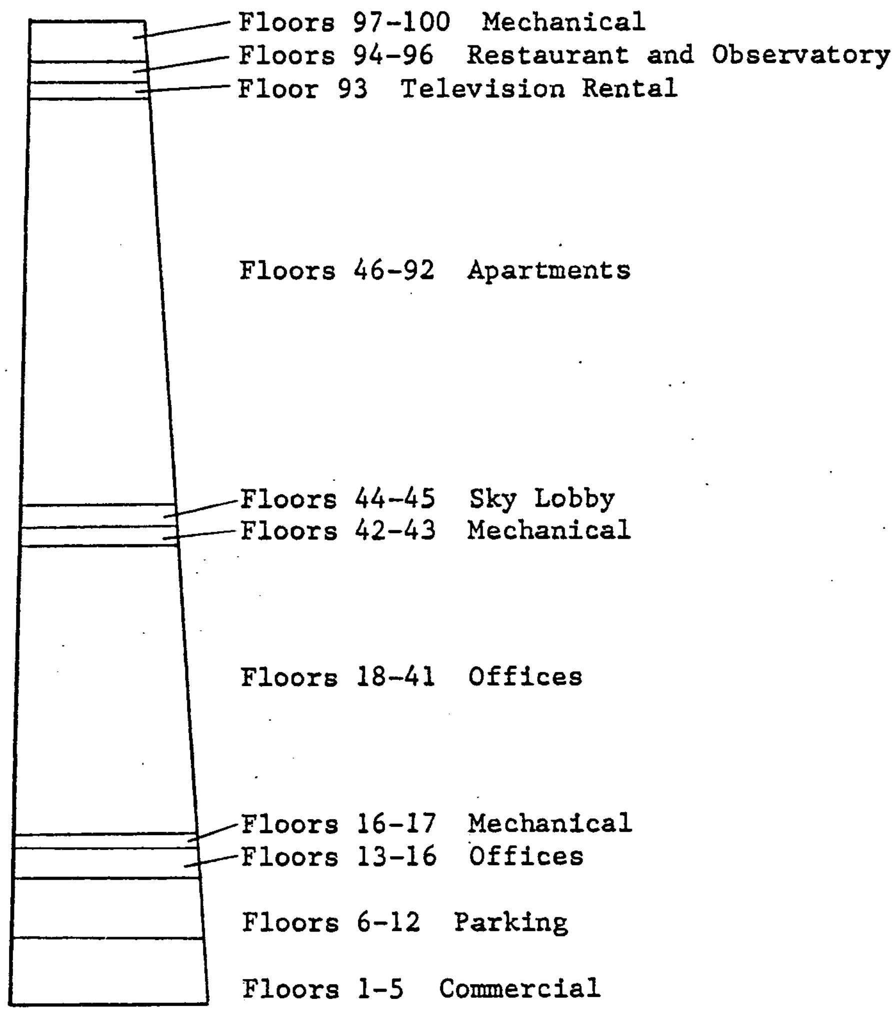

Figure 14: Functions of the John Hancock Center

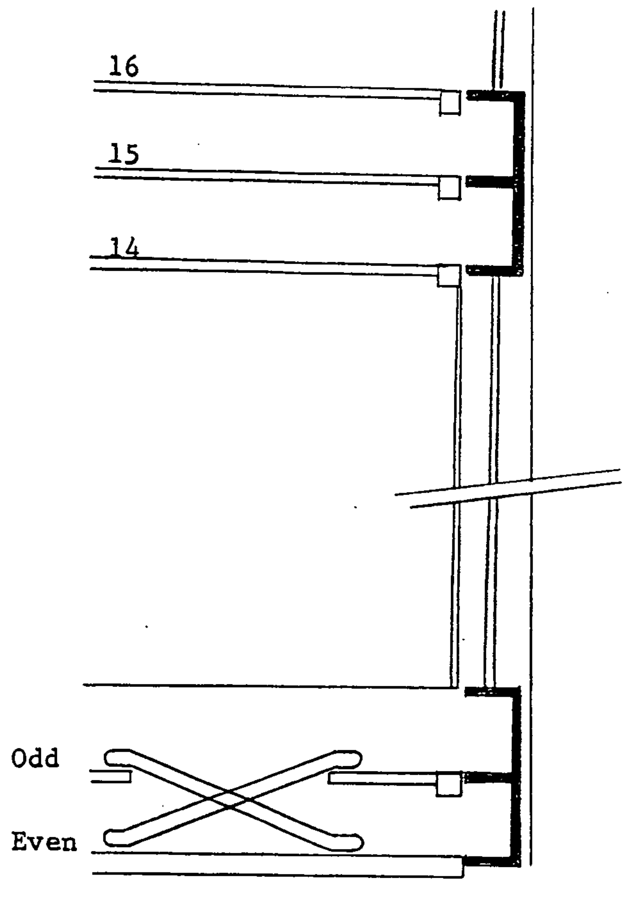

Figure 15: A double-deck elevator system
(Source: Council on Tall Buildings, Chapter SC-4, 1980)

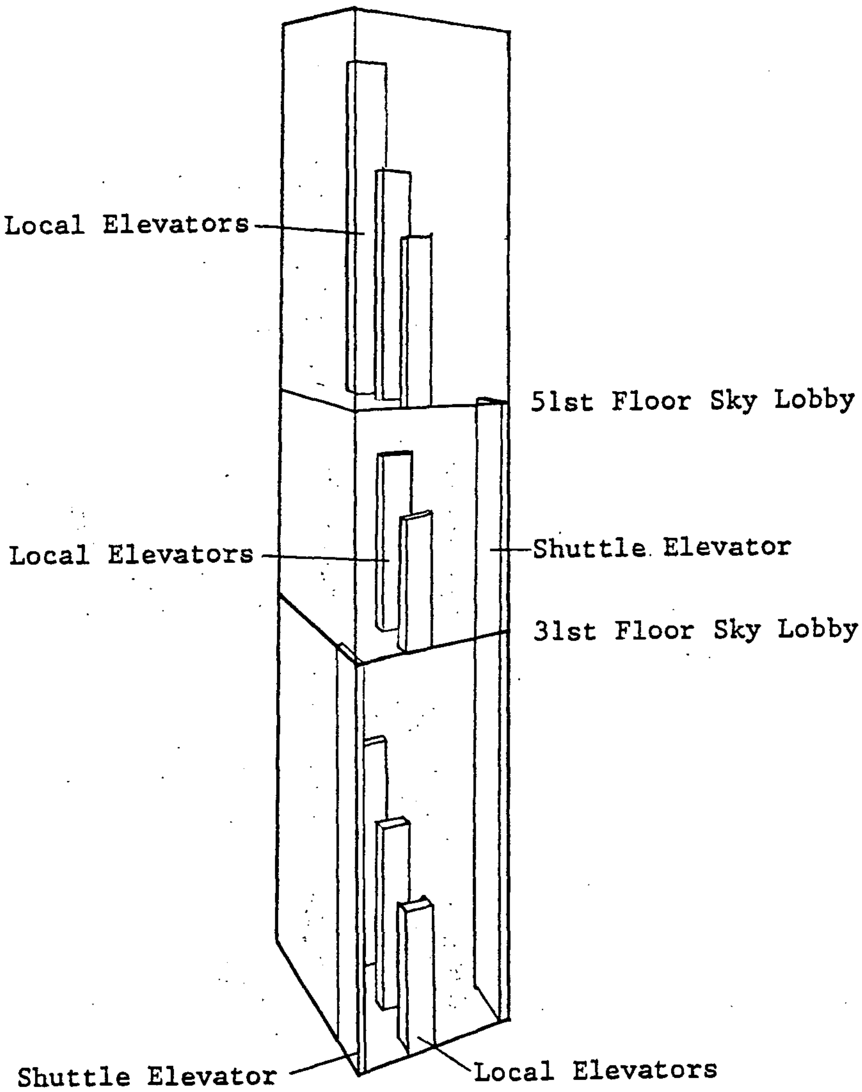

Figure 16: The sky lobby concept
(Source: Council on Tall Buildings, Chapter SC-4, 1980)

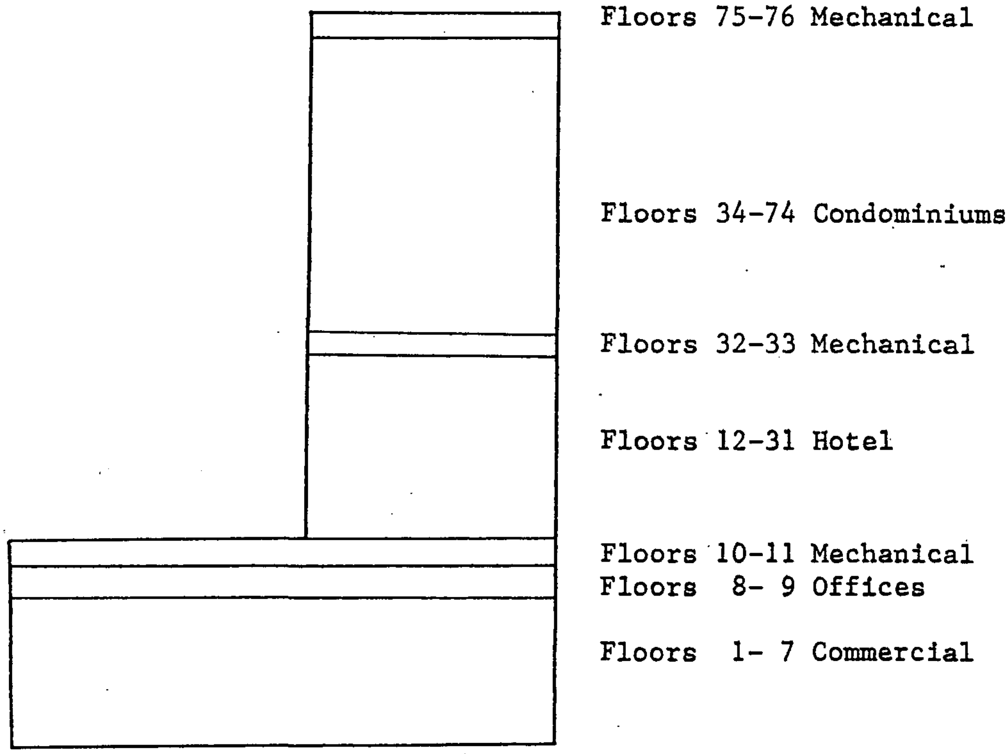

Figure 17: Functions of Water Tower Place

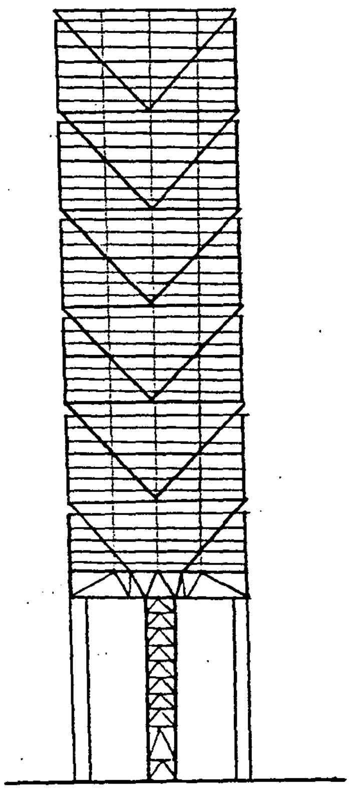

Figure 18: Structural scheme in the Citicorp Center
(Source: Architectural Record, 1976)

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